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Performance Evaluation of the Tanoso Irrigation Scheme in the Brong -Ahafo Region of Ghana

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Abstract - The purpose of the study was to assess the performance of the Tanoso irrigation scheme in terms of distribution uniformity, coefficient of uniformity, water application rate/efficiency, infiltration rate and storage efficiency of the soil. The study was done in Tanoso irrigation scheme where data was obtained through primary and secondary sources between March and April, 2016. Primary data was obtained from interviews, field measurements and field tests while secondary data were obtained through literature review. The data obtained were analysed using efficiency equations and Microsoft Excel. The scheme had an average infiltration rate of 10.32mm/h and an average application rate of 10.13mm/h which indicated that, there is rapid drainage of water in the soil and deep percolation. The distribution uniformity values calculated for both lateral 1 and lateral 2 were 74.04% and 79.7% respectively which indicated that they were all performing according to recommended value of 70% or higher for rotor sprinkler irrigation system. The estimated coefficient of uniformity values for lateral 1 and lateral 2 were 68.08% and 81.8% respectively indicating that they were both performing below recommended value of 85% for vegetable crops and shallow rooted crops. The storage efficiency was calculated to be 40.10% and 55.8% for lateral 1 and lateral 2 respectively, this indicated that the maximum storage efficiency of 100% was not reached for both laterals and that the soil was not capable of holding enough water for crop utilization. Leakages from pipes, main lines, broken weir, dam gates blockage by weeds and malfunctioning riser were some of the problems which affected the efficient performance of the scheme.

Keywords: Performance evaluation, sprinkler irrigation system, distribution uniformity (DU), coefficient of uniformity (CU), water application efficiency, infiltration rate and storage efficiency

1. INTRODUCTION

Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions. Even in areas where total seasonal rainfall is adequate on average, it may be poorly distributed during the year and varied from year to year. Where traditional rain-fed farming is a high-risk enterprise, irrigation can help to ensure stable agricultural production [xiii]. Irrigation schemes are valuable water resources for boosting agricultural production in the world [vi]. With steady increase of the global population, the contribution of irrigation schemes towards boosting agricultural production is enormous [vii]. It had been identified that globally 60% of the diverted fresh water for irrigated agriculture does not contribute directly to food production. This amount of water is wasted because of poor water control, inefficient irrigation systems with leaky conveyance and distribution and poor on-farm water management practices [xvii]. Many irrigation schemes, particularly in least developed and emerging countries, are characterized by a low level of overall performance [xiv].

Performance assessment has been a widely studied subject and concern during the last two decades within the context of diminishing land and water resources and the need to increase productivity of existing irrigation schemes [ii]. Performance is assessed for a variety of reasons, thus to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess impacts of interventions, to diagnose constraints, to better understand determinants of performance, and to compare the performance of a system with others or with the same system over time [xiii]; [i].

The Tanoso irrigation scheme is one of the irrigation schemes in the Brong-Ahafo Region. It was constructed in 1975 and rehabilitated in 2004. It is a sprinkler irrigation system. It is therefore necessary to evaluate whether the current performance of the scheme is efficient or needs to be improved upon to practically benefit farmers in the scheme. Some selected performance indicators including uniformity coefficient, distribution uniformity, average application rate/efficiency and storage efficiency were applied on the scheme. Problems which affected the efficient performance of the irrigation scheme were also identified.

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II. MATERIALS AND METHODOLOGY

Description of Study Area

Tanoso is located in the Techiman Municipality of the Brong Ahafo Region of Ghana. It is situated 15km away from Techiman. It is located between latitudes 7^o 25' and 7^o 28'N and longitude 1^0 56' to 2^oW. Tanoso shares boundaries with Nkoranza in the East, and Offinso in terms of farmland. Tanoso is located in the semi-arid zone of Ghana and it has a mean annual rainfall of 1600mm. The average monthly temperature is approximately 28°C. The average wind speed of the area is 2.29m/s. The community experiences low temperature around July and highest around March. The community is enriched with forty-nine (49) streams and rivers, which are tributaries of Tano River. The topography of the community is generally low lying and undulating. The most abundant soil type is loamy sand. The population of Tanoso is 8,779 representing 4,593 females and 4186 males [ix].

Principal Characteristics of the Scheme

The irrigation scheme is located at Tanoso in the Techiman Municipality. The scheme is a sprinkler type with three electrical pump engines. The project was constructed by the Government of Ghana in the year 1975 through Ghana Irrigation Development Authority (GIDA) and rehabilitated in 2004. The scheme takes its source of water from river Tano and a weir built across it has a length of 18.75m and a crest elevation of 292.7m, with a height of 1.8 m. The pump has a capacity of 55 horse power (hp) with a voltage of 415 volts. The scheme is operated by a pump and sprinkler, which is a fixed rotor type. There exist composite constructed concrete weir and earthen dyke spanning the Tano river, a pump house housing four pumps unit and a 100mm galvanized pipe lines and 50mm pipe lateral and sprinkler heads. The scheme has twenty-five (25) hydrants but eighteen (18) were in good working condition. The scheme also has fifteen (15) risers and 2 cm x 2.5 cm, 3 cm x 2.54cm PVC pipes. The scheme is a fixed rotor type of sprinkler system and has a potential area of 115 ha which benefits about 83 farmers. Crops cultivated under the scheme are okra, pepper, cabbage, tomatoes and watermelon.

Plate 1: Weir Built across the River

Plate 2: Control Room

Plate 3: Crops Cultivated

Data Collection Methods

Field observation and measurements were employed in the gathering of primary data. Catch can test was conducted to measure the uniformity coefficient and distribution uniformity. Thirty (30) catch cans were used for the data collection. Each catch can had a diameter of 120 mm and a height of 115 mm. The cans were arranged on a square grid having a spacing of 3 m x 3 m. The catch cans covered an area of 16 m x 15 m between two sprinklers near the pressure head. Before the experiment was conducted, the pressure head of the sprinkler was measured at a specified pressure and the test was to capture water falling at both sides of the cans arranged along the laterals. The cans were checked and emptied of water before the test was conducted; the sprinkler was made to rotate to collect water into the catch can for a period of time. The experiment was conducted at two locations, lateral 1 (up –stream) and lateral 2 (down -stream). Each test lasted for duration of one hour. After an hour of the experiment, twenty-eight (28) out of the thirty (30) cans received water from the up-stream, and all the thirty (30) catch cans received water from the down-stream, however, care was taken to check overflow of the water in the catch cans. The source of secondary data included reviewing books, articles and newspapers which relates to the study.

Plate 4: Catch Can (Pink colour) Arrangement on the field

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Equations Used Computations in the Study

(i) The average application rate from the sprinklers was computed by:

$I= \frac{kq}{Se \times Sl}$ Where: I= average application rate, mm/min k= conversion constant, 60 for metric units

q= sprinkler discharge, L/min Se= spacing of sprinklers along the laterals, m.

Sl= spacing of laterals along the main line, m [x].

$q = \frac{v}{t}$ Where: v = volume of water collected (litres) and t = container fill time (sec)

(ii) The Distribution Uniformity (DU) indicates the uniformity of application throughout the field and was computed by:

$DU= \frac{\text{Average low quarter depth of water received}}{\text{Average depth of water received}} \times 100$ [x].

(iii) The Coefficient of Uniformity (CU) was computed by:

$CU= 100\left(1.0 - \frac{\sum x}{nm}\right)$ Where: CU = coefficient of uniformity test (mm), $x = |z - m|$ = absolute deviation of the individual observations from the mean (mm), n = number of observations, $m = (\sum z)/n$ = mean depth of observations (mm), z = individual depth of catch observations from uniformity test, mm [x].

(iv) $AE = \frac{(\text{Average Depth of Water applied x Area (ha)})/100}{\text{Water Delivered to the Fied}} \times 100$.

Where AE = Application Efficiency [iv]

$\text{Storage Efficiency} = \frac{\text{Average Depth of water Applied}}{\text{Root Zone Deficit}} \times 100$ [iv]

III. RESULTS AND DISCUSSION

Catch Can Water Collection, Absolute Deviation, Distribution Uniformity and Coefficient of Uniformity

Table 1: Catch Cans Water Collection in Volume (mL), Depth (mm) and Absolute Deviation Results from Upstream and Downstream

Upstream				Downstream			
Catch Can number	**Depth (mm)**	**Volume (ml)**	**Deviation X(z-m)**	**Catch Can number**	**Depth (mm)**	**Volume (ml)**	**Deviation X(z-m)**
1	23	245	9.5	1	13	145	5.8
2	11	125	2.5	2	18	200	0.8
3	12	140	1.5	3	23	245	4.2
4	9	110	4.5	4	21	225	2.2
5	15	170	1.5	5	19	205	0.2
6	11	125	2.5	6	16	175	2.8
7	12	140	1.5	7	23	245	4.2
8	21	210	7.5	8	16	175	2.8
9	16	175	2.5	9	25	260	6.2
10	7	95	6.5	10	15	170	3.8
11	18	200	4.5	11	17	190	1.8
12	8	105	5.5	12	20	220	1.2
13	24	260	10.5	13	18	200	0.8
14	13	145	0.5	14	13	145	5.8
15	18	200	4.5	15	25	260	6.2
16	12	140	1.5	16	16	175	2.8
17	6	90	7.5	17	24	260	5.2
18	20	220	6.5	18	13	145	5.8
19	12	140	1.5	19	21	225	2.2
20	15	170	1.5	20	23	245	4.2

21	18	200	4.5	21	16	175	2.8
22	0	0	0	22	18	200	0.8
23	9	110	4.5	23	21	200	2.2
24	17	190	3.5	24	25	260	6.2
25	23	245	9.5	25	16	175	2.8
26	11	125	2.5	26	18	200	2.8
27	25	260	11.5	27	12	140	6.8
28	13	145	0.5	28	24	260	5.2
29	0	0	0	29	20	220	1.2
30	5	85	8.5	30	16	175	2.8
Sum	**404**	**4565**	**129**	**Sum**	**565**	**6115**	**102.6**
Average	**13.5**	**152.2**		**Average**	**18.8**	**203.8**	

Table 1 showed that out of the thirty (30) catch cans, twenty eight (28) of the cans received water from sprinklers 1 and 2 for the up-stream while all the cans received water for the down-stream. The catch can pattern was spaced 16m by 15m along the two sprinklers which represents one hour (1hr) of irrigation, from lateral 1. For the up-stream twenty eight (28) catch cans collected a depth of 404mm of water with an average of 13.5mm, two (2) of the catch can did not collect water from the sprinklers, while the remaining cans receive about 100ml to 150ml. Catch can number 27 collected the highest volume of water which is 260ml representing 5.69% of the total volume of water collected while catch can number 30 collected the least volume of water which is 85ml representing 1.86% of the total volume of water. This means that water distribution is not uniform making some parts of the soil receiving more volume of water than other parts of the soil. This may be due to the wind effects at that time, directing water movement towards south. The pressure of the water and the distance of throw of the water can also be an effect of this occurrence.

From lateral 2 (down-stream), and presented in table 1, all the thirty catch cans received water for the sprinklers, the average depth of water collected from the test was 18.8mm. This catch can number 9, 15 and 24 received the highest volume of water. It was observed that the distribution of water on the soil is more uniform in lateral 2 (down-stream) that in lateral 1(up-stream). This occurrence could be due to the pressure at the sprinkler head and the distance of conveyance of water to the field, as the water source is more closer to the lateral 2 (down- stream) than lateral 1.

The absolute deviations values (z-m) for the depth of water was used to calculate the uniformity coefficient (CU) , and the average of the lowest quartile of the catch cans, 8 out of 30 cans were used to determine distribution uniformity (DU), for both catch can test results on lateral 1 (up-stream) and lateral 2 (down-stream).

Table 2: Values for DU, CU, and Average Catch Depth for the Sprinkler Spacing in Area of 16 m by 15 m

Test Area (16 m x15 m)	**Average Low-quarter (mm)**	**Average catch depth (mm)**	**Distribution Uniformity (DU) %**	**Coefficient of Uniformity (CU) %**	**Storage Efficiency (S.E) %**
Area between sprinklers 1 and 2 (Up-stream)	10	13.5	74.04	68.06	40.1
Area between sprinkler 1 and 2 (Down-stream)	15	18.8	79.7	81.8	55.8

From Table 2, the results obtained showed that lateral 1 (up-stream) has an average distribution uniformity (DU) of 74.04%. According to [xv], the recommended value for distribution uniformity (DU) should be 70% or higher for rotor sprinkler irrigation system. This indicates that lateral 1 (up-stream) was performing according to recommended value. The average distribution uniformity obtained from lateral 2 (down-stream) was calculated to be 79.7%, which also indicates that lateral two was performing well. The value of DU decreases as a

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result of changes in uniform application of water to get to every part within the irrigated area increases [xvi]

In the study of [v], the main effect of sprinkler irrigation is environmental factors and the CU value is clearly affected by wind speed beyond 2.1m/s. The sprinklers from the schemes operated at 310kpa and 320kpa pressures and good environmental conditions (average wind velocity of 2.7m/s, high relative humidity of 63% and low temperatures of 28°C) during the field measurements. Merkley and Allen [xii] indicated that, wind speed can help increase the uniformity as the randomness of the wind direction affects the uniform distribution pattern. From Table 2, the Coefficient of Uniformity (CU) for lateral 1 (up-stream) was estimated to be 68.06%, and 81.8% for lateral 2 (down-stream) According to [x], CU greater than 70% forms a bell-shaped normal distribution. Little *et al.* (1993) reported that the Soil Conservation Service (SCS) classified uniformity of a sprinkler irrigation system as worse, poor, good and very good if the CU values is less than 69%, between 70% and 79%, between 80% and 89%, and 90% respectively. The CU value of 68.08% for lateral 1 (up-stream) was found to be lower than the recommended value of CU for vegetables crops cultivation. However, the CU value for lateral 2 (down-stream) was estimated to be 81.8% which was also below the recommended CU value of 85% [x] for vegetable crops and shallow rooted crops.

Average Application Rate and Infiltration Rate of the Soil

The average application rate was determined using a container of volume 1.5 litres to estimate the discharge from two sprinklers. The average discharge was calculated to be 40.54L/min. The application rate was also determined to be 10.13mm/h. Infiltration test was conducted along three laterals (up-stream, middle stream, down- stream) to determine the average infiltration rate of the soil. The application rate was calculated to be 10.13mm/h, while the average infiltration rate of the soil was 10.32mm/h. Infiltration rate determines the rate at which water moves vertically down into the soil and the potential for runoff. From the analysis, the average application rate of 10.13mm/h was less than infiltration rate, which causes deep percolation and rapid drainage of water. It shows that all the water applied during irrigation is infiltrated into the soil. This implies that, the field is receives less water than required.

Plate 5: Infiltration Test on the Irrigable Area Using Mini-disk Infiltrometer

Application Efficiency

With an average catch can depth of 13.5mm for lateral 1 and 18.8mm for lateral 2 applied over an area of 0.024(ha) with average flow of 0.0135 for lateral 1 and 0.0188 for lateral 2 for an irrigation duration of one hour, the application efficiency was calculated to be 24% for both laterals. This low value of efficiency is due to the high value of losses during application and poor conveyance structure, leakages in pipes and defunct riser. According to [iii] efficiency of sprinkler irrigation is in the range of 70-95%, but can be much lower due to poor design or management, as in the case of Tanoso irrigation scheme.

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Storage Efficiency

Table 3: Correlation between Texture and other Soil Properties

SS	OCc (%)	OMc (%)	Sand (%)	Silt (%)	Clay (%)	Soil Type	FC (cm/m)	PWP (cm/m)	RS (s)	BD (g/cm^3)	HC (mm/hr)
US	0.68	1.2	89.84	1.92	8.24	Sand	9.6	5.4	42.5	1.52	81.1
MS	0.56	1.0	85.84	3.92	10.24	Loamy sand	11.4	6.5	41.6	1.55	63.1
DS	0.55	0.94	91.68	0.08	8.24	Sand	7.9	3.9	42.9	1.51	100.1
Av	**0.59**	**1.04**	**89.1**	**2.0**	**8.9**	**Loamy sand**	**9.6**	**5.2**	**42.3**	**1.53**	**81.4**

Where: SS-Sample Site, US – Upstream, DS – Downtream, MS- Midstream, Av – Average, OCc – Organic Carbon Content, OMc – Organic Matter Content, FC – Field Capacity, PWP – Permanent Wilting Point, RS – Relatvie Saturation, BD – Bulk Density, HC – Hydraulic Conductivity

Table 3 presents the analysis report of three soil samples from the irrigation scheme. Considering the root zone depth of 1m and manageable allowable deficit of 50%, and the total available water content of the soil to be 67.32mm/m, the root zone deficit was calculated to be 33.66mm/m. From Table 2, the average catch can depth was 13.5mm and 18.8mm for lateral 1 and lateral 2 respectively. Storage efficiency (SE) was computed to be 40.1% and 55.8% for lateral 1 and lateral 2 respectively. This means that, the maximum storage efficiency of 100% was not reached for both laterals on the field, and soil from both laterals are not capable of storing enough water for crop utilization, and also the irrigation water was less applied to the field as the Net Irrigation Requirement (NIR) was not met.

Challenges Associated with the Irrigation Scheme

The study from the catch can test revealed that the major challenge of the efficiency was the poor distribution uniformity which was caused by high wind effect. Wind effects have influence on the application pattern of a sprinkler irrigation system that can be reduced by decreasing the distance between the nozzle along the laterals and during design of the system with increasing wind velocity [x]. Electricity being the power source for the operation of the pump, high utility tariffs was also another challenge that has made it difficult for farmers to irrigate their crops adequately; they paid high charges for short period of irrigation.

Leakages from pipes, main lines, broken weir, dam gates blockage by weeds, riser mal-function, were also another challenge for quality water conveyance to the field causing runoff and soil erosion. According to the farmers, there were not much pipe lines and sprinkler riser. This made it difficult to convey water to the upper parts of the field and distant farm site were unable to undergo irrigation due to these challenges. All these challenges tend to affect the distribution uniformity of the sprinkler in the scheme.

The management of the scheme revealed that many of the farmers were unable to pay their irrigation service charge which made it difficult for the maintenance and repairs of the facility resulting in the overall performance of the scheme being affected slightly. They added that, there were less staff for proper supervision of the scheme and engineers to educate farmer on the proper utilization of the equipment, also the scheme has not been rehabilitated for quite a number of years now leaving the facility in a poor condition.

Plate : Malfunction Riser and Leakages from Pipes

Plate: Blockage of Weeds at Water Suction Point

IV. CONCLUSION

The study revealed that the average application rate of the sprinkler was 10.13mm/h which was slightly lower than the average infiltration rate of 10.32mm/hr. The values for Distribution uniformity for both lateral 1 and lateral 2 were calculated to be 74.04% and 79.7% respectively, and both were above the recommended value (70%) as a result of stable wind speed and good sprinkler performance. The coefficient of uniformity (CU) for both lateral 1 and lateral 2 were calculated to be 68.06% and 81.8% respectively which were also below the recommended value of 85% for vegetable production using rotor type sprinklers. The average depth of water applied was lower than the root zone deficit giving a storage efficiency of 40.1% and 55.8% for both lateral 1 and lateral 2 respectively. Application efficiency was also very poor at 24% for both laterals.

To improve upon the performance of the irrigation scheme, the following are recommended:

- Employment of permanent engineers and skilled personnel,
- MeasureS should be put in place to ensure payment of irrigation service charge for regular repairs and maintenance,
- There should be proper supervision of the irrigation scheme,
- Frequent performance evaluation and monitoring should be carried, and
- Supply of adequate sprinkler irrigation equipment and repair all malfunctioning equipment.

REFERENCES

i. *Adongo, T. A., Abagale, F. K., Kranjac-Berisavljevic, G. (2016). Performance Assessment of Irrigation Schemes in Northern Ghana Using Comparative Performance Indicators. International Journal of Scientific Engineering and Technology, Vol.5(4), ISSN(online) 2277-1581, pp. 217-224*

ii. *Cakmak, B., Polat, H. E., Kendirli, B. and Gokalp, Z. (2009). Evaluation of Irrigation Performance of Asartepe Irrigation Scheme Association: A Case Study from Turkey. Akdeniz University, Ziraat Fakultesi, Dergisi, Vol. 22(1): 1 – 8.*

iii. *Danny H. R., Freddie R. L., Mahbub A., Todd P. T., Gary A. C., Philip L. B. and Kyle M.(1997). Irrigation management series. Cooperative Extension Service, Kansas State University, Manhattan.*

iv. *David, W. and Steven R. (2001). Measuring irrigation system in the Queensland Dairy Industry.University of Southern Queensland, Brisbane, Austria. 1-23.*

v. *Dechmi, F., E. Playan, J. M., Faci and Tejero, M. (2003). Analysis of an irrigation district in north-eastern Spain. I. Characterisation and water use assessment. Agric. Water Manage., 61:75-92*

vi. *Degirmenci, H., Buyukcangaz, H. and Kuscu, H. (2003). Assessment of Irrigation Schemes with Comparative Indicators in the Southeastern Anatolia Project. Turk J. for Agric, 27: 293 – 303.*

vii. *FAO (2005): Agriculture, Food and Water, Natural Resources Management and Environment Department, http://www.fao.org/DOCREP/006/Y4683E/Y4683E00.HTM. Rome, Italy: Food and Agriculture Organization of the United Nations*

viii. *FAO (2007). Gender and Food Security. Synthesis Report of Regional Documents: Africa, Asia and Pacific, Europe, Near East, Latin America.*

ix. *Ghana Statistical Service (2010). Population and Housing Census Records.*

x. *Keller, J. and Bliesner, R. D. (1990). Sprinkle and Trickle Irrigation, Van Nostrand Reinhold. New York.3-5, 86-96*

xi. *Little, G. E., Hills, D. J. and Hanson, B. R. (1993). Uniformity in pressured irrigation system depends on design installation. California Agric., 47: 18-21.*

xii. *Merkley, G. P. and Allen, R. G. (2004). Sprinkle and Trickle Irrigation Lecture Notes, Utah State University, USA.*

ISSN:2277-1581
01 Nov. 2016

xiii. *Molden, D. J., Sakthivadivel R., Perry, C. J., Fraiture, D. C. and Kloezen, W. H. (1998). Indicators for comparing performance of irrigated agricultural systems. Research Report 20, Colombo, Sri Lanka: International Water Management Institute. 26p.*

xiv. *Sayin, B., Karaman, S., Yilmaz, I. and Celikyurt, M. A. (2013). Assessment of the performance of participatory irrigation management in Antalya, Turkey. Water Policy 15: 269 – 280.*

xv. *Tim P. W. and David F. Z., (1997). Evaluating Sprinkler Irrigation Uniformity. CATI, Publication No 970703. http:cati.csufresno.edu.*

xvi. *Wigginton, D.W. Raine, S.R. (2001). Measuring Irrigation System Performance in the Queensland Dairy Industry. National Centre for Engineering in Agriculture Publication 179729/5. Toowoomba, Australia.www.landwise.org.nz*

xvii. *World Agricultural Forum (2009): World Congress Proceedings: Creating Prosperity by Investing in Agriculture. Kampala, Uganda.*